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THE EFFECT OF MONOLITHIC PACKING ON GATEROAD PERFORMANCE AT LINGAN COLLIERY

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October 1985

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THE EFFECT OF MONOLITHIC PACKING ON GATEROAD PERFORMANCE AT LINGAN COLLIERY

by

Peter Cain*

ABSTRACT

A monolithic packing system was installed in the 9E Maingate at Lingan Colliery, New Waterford, in an attempt to reduce air loss through the waste. The performance of the gateroad before and after the implementation of the new packing method was monitored so that any deleterious effects of the change might be detected and corrected at an early stage. This report describes the investigation programme and the effects of the packing change determined from the investigation results, from which it was determined that the deformation behaviour of the roadway was virtually unchanged.

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EFFET DU REMBLAYAGE MONOLITHIQUE SUR LA PERFORMANCE DE LA GALERIE DE DESSERTE DE LA HOUILLÈRE LINGAN

par

Peter Cain*

RÉSUMÉ

Un système de remblayage monolithique a été installé à la galerie principale 9E de la houillère Lingan, New Waterford, dans le but de réduire les pertes d'air dans le remblai. La performance de la galerie de desserte avant et après la mise en application de la nouvelle méthode de remblayage a fait l'objet d'un contrôle visant à détecter et corriger tout effet délétère dès le début. Le rapport présente une description du programme d'investigation et les résultats découlant du changement de remblayage qui ont été observés à la suite de l'investigation. Celle-ci a permis de déterminer que le processus de déformation de la galerie demeurait pratiquement inchangé.

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INTRODUCTION

The loss of large quantities of ventilating intake air to return airways by leakage through the longwall wastes has long been recognised as a problem at Lingan Colliery, especially on the east side panels (Figure 1) (1,2). Production scheduling at the colliery currently requires the simultaneous extraction of two adjacent longwall faces, 8E and 9E, which precludes the use of the most effective leakage control method previously utilised, 'cundy ventilation' (Figure 2). In an effort to prevent gob leakage and allow safe and efficient production from both active east side panels, the Cape Breton Development Corporation (CBDC) decided to implement a monolithic pumped packing trial on the 9E Maingate. The Cape Breton Coal Research Laboratory (CBCRL) was involved at an early stage in the planning of the trial and was asked to investigate the effects of the packing change on strata control and gob leakage. This report presents details and results of the strata control investigation based on three investigation sites in the 9E Maingate and follow up gateroad surveys. The behaviour of the conventional and monolithic packed sections of the maingate are compared and conclusions drawn relating to current mining practise and investigation methods.

INVESTIGATION METHOD

During the planning of the monolithic packing trial a proposal for an investigation package was presented to CBDC (3), based on previous investigation methods used in the coalfield. This package consisted of two parts: 1) detailed site monitoring and 2) additional monitoring including gateroad deformation surveys.

The proposed site monitoring programme included the use of a variety of instruments to monitor support load, closure and differential strata movement (Table 1). The additional monitoring covered five parameters; survey levelling of convergence pins to determine relative roof and floor movement, monitoring of pack grout quality, pack mixture and ambient temperatures, gateroad surveys to determine overall deformation characteristics and rate of face advance. Monitoring of pack grout quality and pack mixture and the ambient temperature were later removed from the programme on the advice

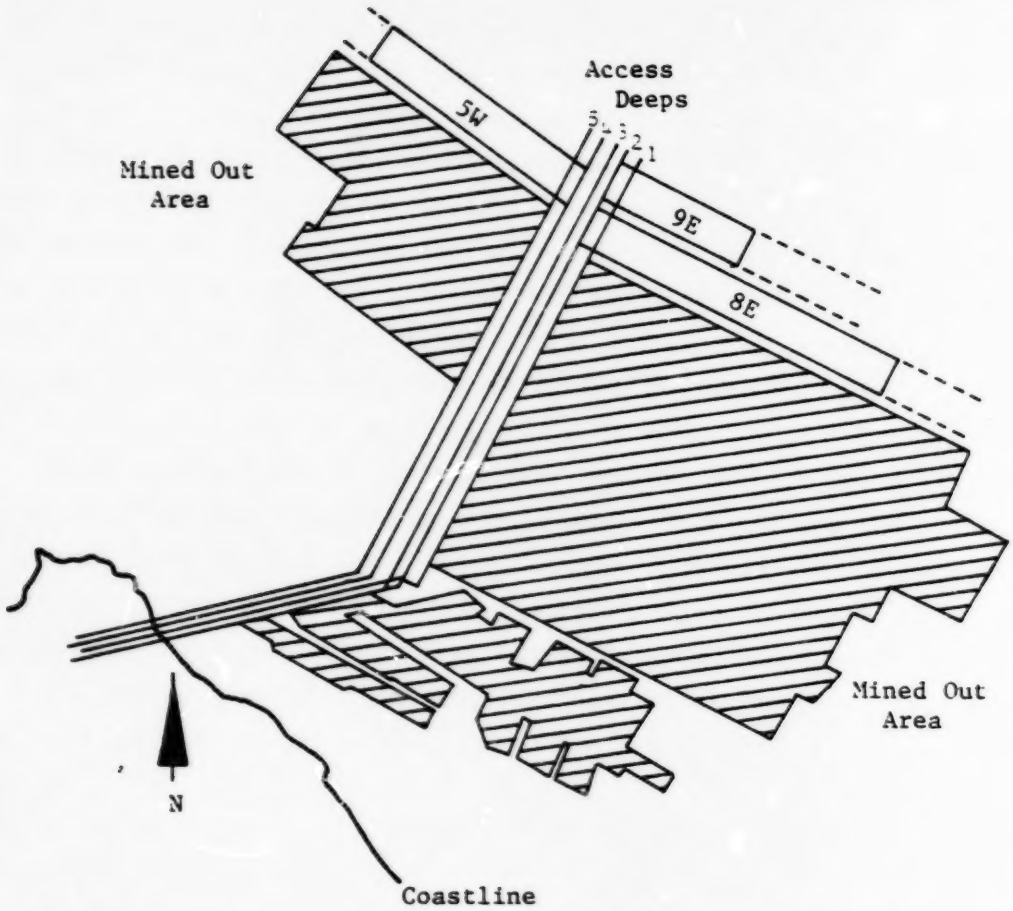


Figure 1 - Lingan Colliery, New Waterford, Nova Scotia

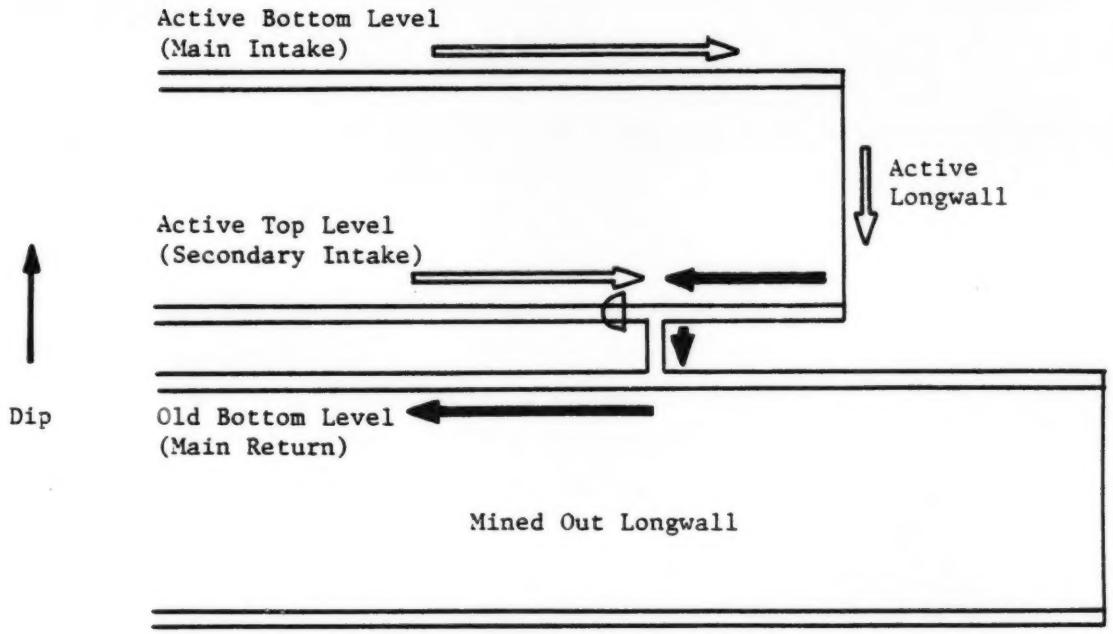


Figure 2 - 'Cundy ventilation' as practised at Lingan Colliery

of the technical specialist from the manufacturers of the packing material, but the rest of the programme was implemented as planned, with minor adjustments to instrumentation patterns at the individual sites.

Table 1 - Instrumentation used in the investigation programme

Parameter	Instrumentation
Closure: Gateroad	- Rock bolts in roof and floor.
Closure: Packs	- Electronic resistance pack strut (Model Cor/P-R, Roctest Inc., Montreal)
Load: Packs	- Earth pressure cell, hydraulic readout 0-1000 psi (Solinst Canada Ltd., Burlington)
Differential Strata Movement	- Irad Gage Flexible Sonic Probe (Solinst Canada Ltd., Burlington)

DETAILS OF THE 9E DISTRICT

Some details concerning mining parameters affecting the 9E panel are given here to allow comparison between this study and investigations elsewhere.

MINING PARAMETERS

The 9E Panel at Lingan Colliery (Figure 1) is a 217 m wide longwall advancing district. Coal is won from the 2.1 m thick Harbour Seam by a 224 kW (300 hp) Anderson Mavor double ended ranging drum shearer. The web is 0.68 m. The face supports are Hemscheidt 320 tonne two-leg shields and are operated one web back. Coal cutting is bi-directional.

The panel has a planned length of 2600 m and dips a few degrees off strike giving a range of depths of cover from 550 m close to the deeps to 610 m at its furthest point. It is protected from the effects of the adjacent panel, 8E, by a 76 m wide barrier pillar.

SUPPORT IN THE TRIAL ROADWAY

Prior to the implementation of monolithic packing, the maingate pack consisted of a continuous row of 1.75 m x 1.75 m, 80% solid hardwood chocks adjacent to the arch. On the gob side of this was a 30 cm wide wall of stonedust in 25 kg bags and a 0.75 m x 1.75 m skeleton hardwood crib built just behind the panline. Intermittent 1.5 m x 0.75 m skeleton wood chocks were also built on the ribside where the coal is extracted to a distance of approximately 1.5 m below the ribside leg of the arch. The pack was usually built mid-way between the face and the ripping lip, a distance of approximately 8 - 10 m (Figure 3). The roadway support consisted of 120 mm x 90 mm I section steel arches with a diameter of 4.2 m and 1.2 m splayed legs. The steel section was 29.5 kg/m. The arches were set at 0.9 m intervals strutted with 63 mm x 63 mm x 63 mm angle iron struts u-bolted to the arch and lagged over the crown with softwood. A Dosco DRCL MKIIA was used to cut the roadway.

Before the packing change was made, CBDC solicited the advice of CBCRL on the width of monolithic pack required to support the roadway. Using published data on pump pack properties and experimental results from other investigation sites at Lingan Colliery and taking into account the layout of the existing face end, a pack width of 2.1 m was suggested (4). This is summarised in Appendix A. This was implemented by replacing the hardwood chock and the stonedust wall with the monolithic pack. The additional 30 cm in pack width was accommodated easily within the existing face end layout. All other gateroad support parameters remained constant, except for some additional wood or corrugated steel lagging between the monolithic pack and the arch leg to prevent excessive spalling into the roadway.

THE 'ASTRAPACK' PACKING SYSTEM

'Astrapack' is a low solids cement based packing material recently developed by Pozzament Cements Limited to compete with the 'Tekpack' product offered by Foseco. The latter has been used in the U.K. with success for two years. 'Astrapack' was chosen for the trial after a competitive bidding process.

The trial was initiated in March 1985 after the panel had advanced 617 m. The 'Astrapack' system requires less material to be imported than 'Tekpack' or its predecessor 'Aquapack', a similar packing system

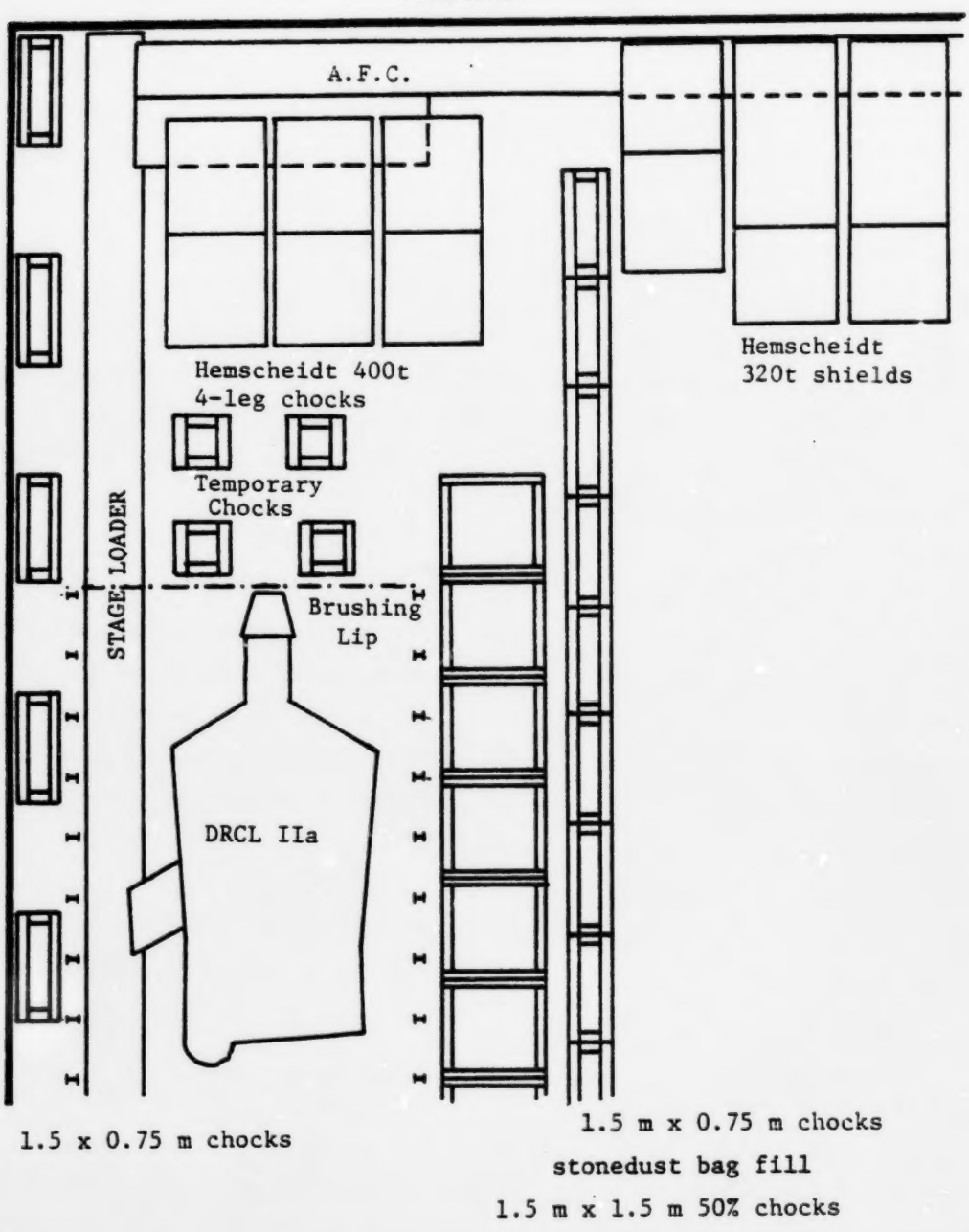


Figure 3 - Maingate support in the 9E Maingate prior to the implementation of monolithic packing

manufactured by Pozzament Ltd. (Table 2). The placing equipment was left over from a previous short-lived experiment with 'Aquapack' elsewhere in the mine. The cement grout pump was mounted over the stageloader at the face end, with the bentonite grout pump located outbye at the No. 4 deeps landing (Figure 4). A shutter built by CBDC to NCB design and locally made packing bags allowed the 2.1 m wide, 2.1 m high pack to be placed in 1.2 m increments, though this was later increased to 1.5 increments by using longer bags.

A preliminary report on the packing system employed at Lingan Colliery has been published (5) and for convenience is summarised in Appendix B.

Table 2 - Mix ratios of 'Aquapack', 'Tekpack' and 'Astrapack' (quantities per m^3 of pack)

	cement component kg	bentonite/ accelerator kg	water kg
Aquapack	450	50	915
Tekpack	182	182	910
Astrapack	175	175	876

ROADWAY GEOLOGY AND STRATA PROPERTIES

The 9E Maingate has been mapped along its length by CBDC geological staff. Thus the immediate roof and floor lithologies are well documented. No cored boreholes have been undertaken in any gateroads at Lingan Colliery, but methane drainage holes drilled in the tailgate have been monitored and the chippings logged. Roof lithologies are presented diagrammatically along the length of 9E Maingate in Figure 5. A generalised strata section for the 9E Maingate is given in Table 3.

Due to the lack of core samples, very little data concerning the strength properties of the surrounding strata is available. One methane drainage borehole located 319 m from the start of the wall on the material level was logged from chip samples which were subsequently index tested using the NCB Cone Indentor. The logs derived from this borehole are given in Figure 6. The range of mechanical properties derived from cores of strata encountered in other parts of the coalfield are given in Table 4. Coal properties have been investigated more extensively. Physical properties of the Harbour Seam at Lingan Colliery are given in Table 5.

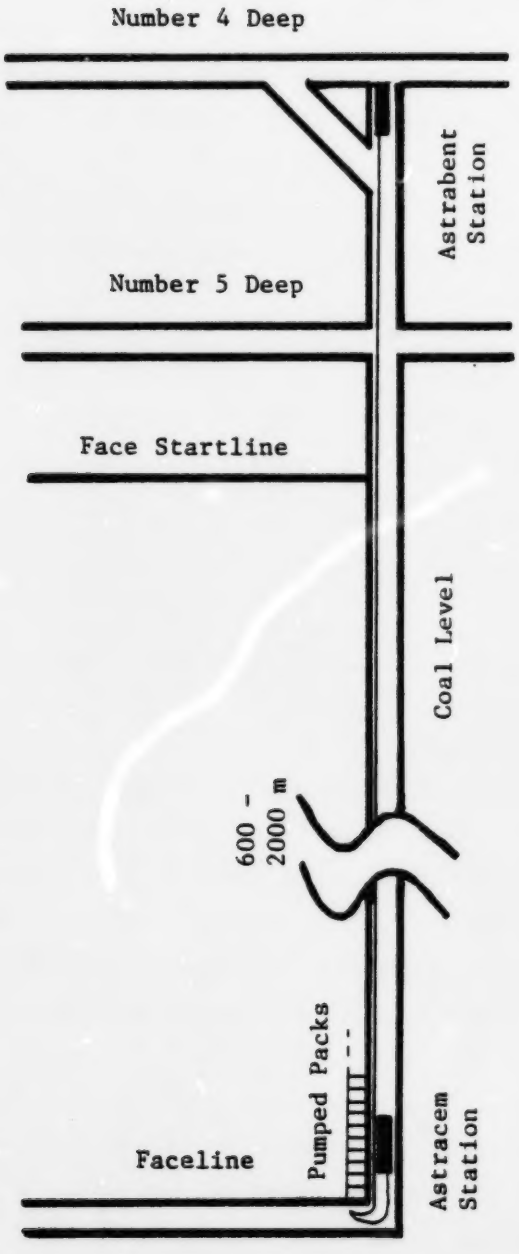
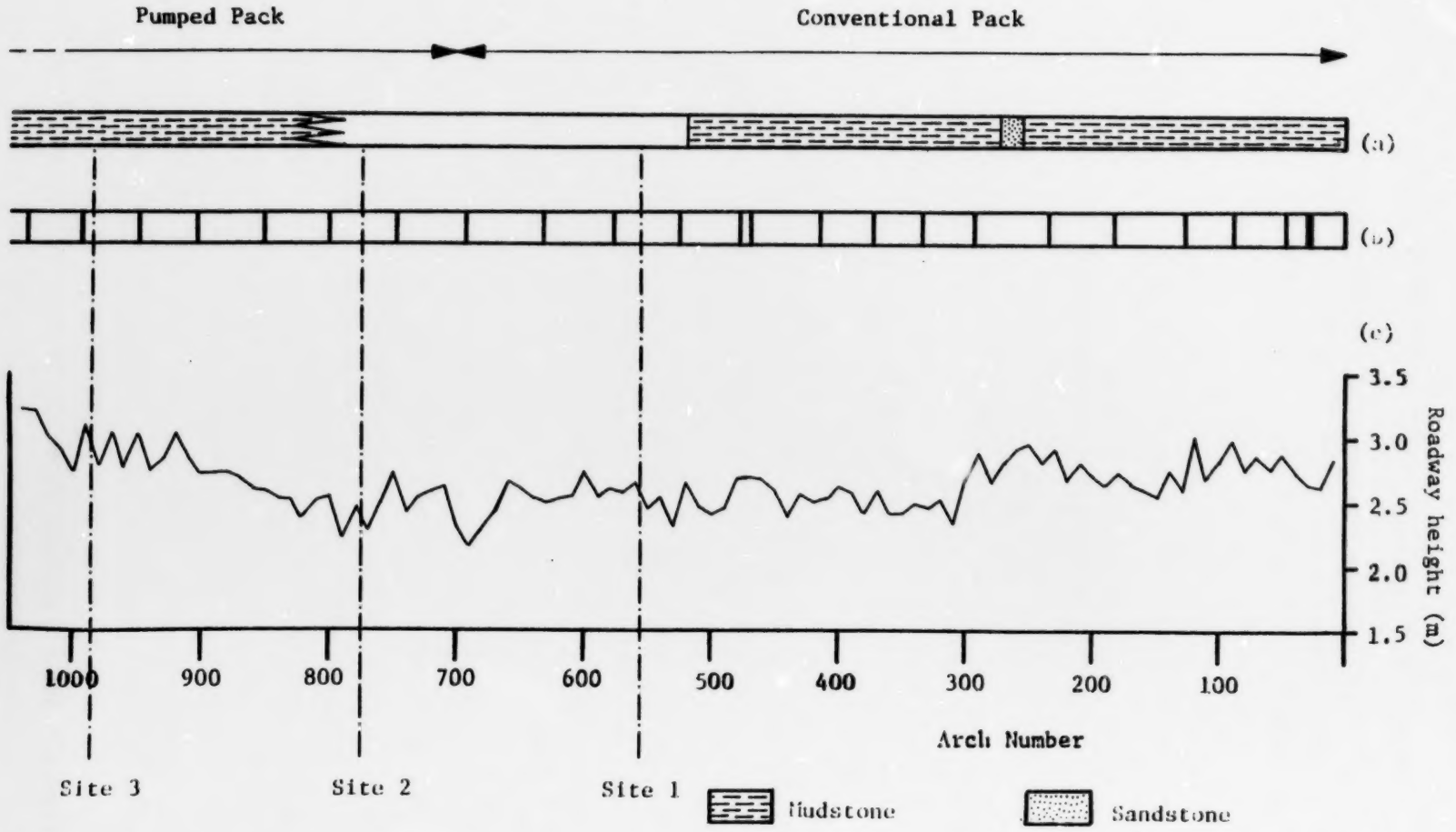


Figure 4 - Schematic layout of pump packing equipment in the 9E Maingate, Lingan Colliery



a) Generalised roadway geology

b) Face advance in two week increments

c) Roadway height (last arch 1041)

Figure 5 - Location of investigation sites in the 9E Maingate with respect to roof geology and face advance and showing gateroad height profile

Table 3 - Generalised strata section of the 9E Maingate

Freshwater siltstones and mudstones containing braided sandstone channels, overbank deposits represented by laminites and occasional sandy limestones.
Harbour Seam: 2.1 m thick
Siltstone Seatearth: rootlets, listric surfaces
Shale

DETAILS OF THE INVESTIGATION SITES

A total of three investigation sites have been installed in the 9E Maingate, one prior to the packing change and two subsequently. This location relative to roadway geology and each other in the gateroad is shown in Figure 5. Information concerning depth of cover, extracted height and other site specific parameters is given in Table 6. Geological sections of the roof strata, mapped by CBDC geologists are shown in Figure 7.

SITE INSTRUMENTATION

Instrumentation at each site was installed on two consecutive day shifts; firstly the pack instrumentation, load cells and pack struts, on a working shift, followed on a Saturday morning by the gateroad bolt closure stations. In this way unnecessary congestion at the face was avoided. A summary of instruments used at each site is given in Table 7. A scale plan of each site is given in Figures 8, 9 and 10. Despite the great care taken during installation to protect the instruments and their readout cables, several became inoperative or gave results which gave rise to the suspicion of malfunction after a short period of time. This is understandable due to the adverse conditions under which they operate and some losses in this manner are inevitable. Other readings were lost due to deliberate tampering or vandalism, most noticeably convergence readings from rock bolts. Thus a complete picture of gateroad behaviour is impossible in some instances.

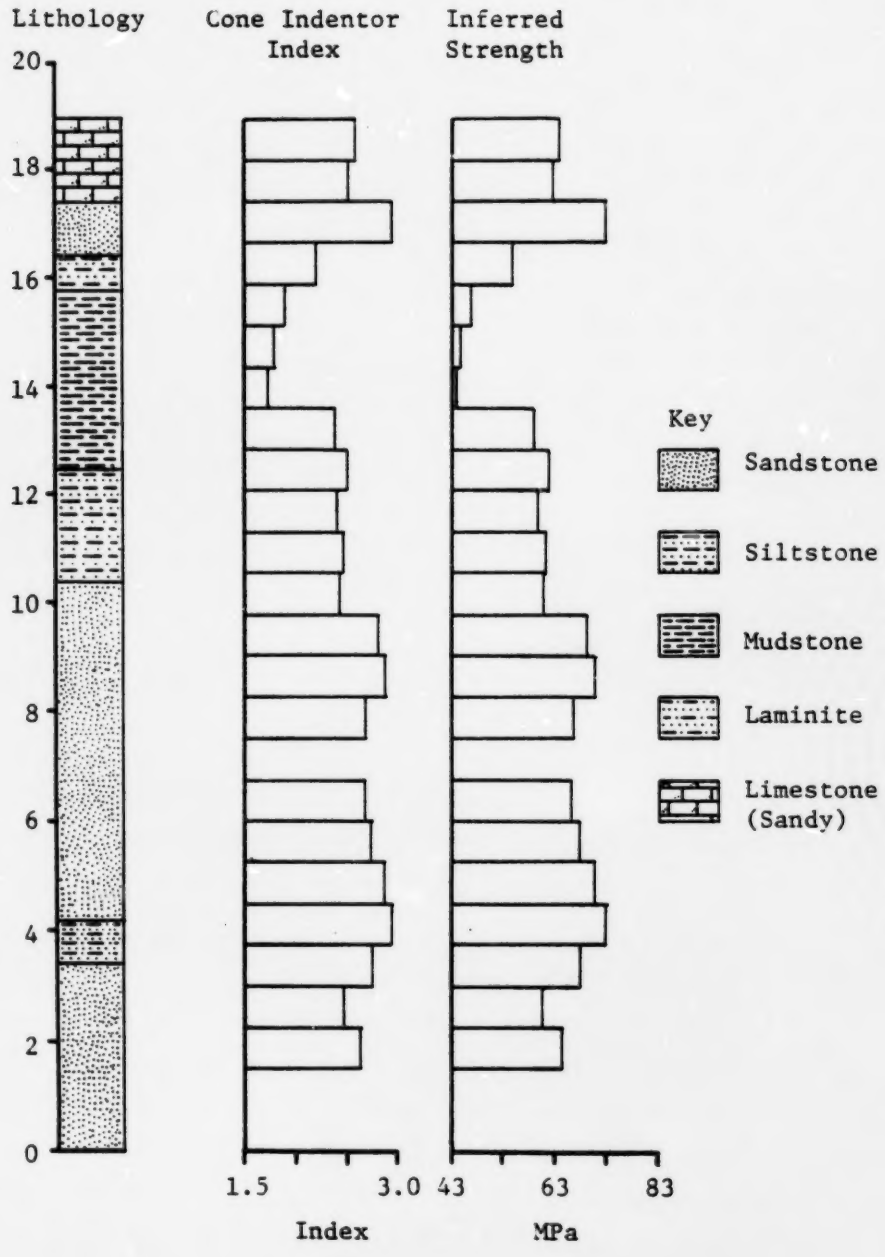


Figure 6 - Lithology, cone indentor index and inferred compressive strength log of methane drainage hole L9E1, 9E Tailgate, Lingan Colliery

Table 4 - Physical properties of comparable strata from elsewhere in the coalfield

Strata Type	Uniaxial Compressive Strength (MPa)	Tensile Strength (MPa)	Youngs Modulus (GPa)	Poissons Ratio
Sandstone	72-80	3.8-8.1	17	0.28
Siltstone	60-100	2.6-10.4	13-19	0.14-0.2
Mudstone	30	0.7-5.6	28	0.25
Laminite	57-67	5.4-7.7	11-15	0.16
Limestone	42.6	9.6	13	0.17

Table 5 - Physical properties of the Harbour Seam at Lingan Colliery

Point Load Index (Is_{54})	1.23
Uniaxial Compressive Strength (MPa)	11.8
Youngs Modulus (GPa)	1.4-2.9
Poissons Ratio	0.34
Ø Peak	30°
Ø Residual	30°
Permeability	8-14 microdarcies
Hardgrove Grindability Index	56-62

SITE MONITORING

Instrumentation at each site was monitored daily for the first week after installation and at a reducing frequency after that as the faceline moved away from the site.

Table 6 - Site specific parameters, 9E Coal Road, Lingan Colliery

Parameter	Site 1	Site 2	Site 3
Depth of Cover (m)	576	580	583
Extracted Height (m)	2.17	2.10	2.11
Seam Dip (degrees)	6.7	6.9	6.5
Pillar Width			
Maingate (m)	infinite	infinite	infinite
Tailgate (m)	162.4	72	76.8
Rate of Face Advance first 4 weeks past site m/day	3.7	3.2	3.2

Table 7 - Summary of instruments deployed at each investigation site

	Convergence Bolts	Load Cells Pack	Pack Struts
Site 1	2 pairs, on rib and pack side and a single centre bolt in the roof	4 in the 1.5 x 1.5 m wood crib	2 in the pack, 1 in line with the bolt section
Site 2	As above	3 below the pumped pack, two mounted vertically to measure lateral load	2 in the pack
Site 3	As above	As above	1 in the pack

In addition, a 7.5 m extensometer hole was drilled vertically above the roadway at Site 3

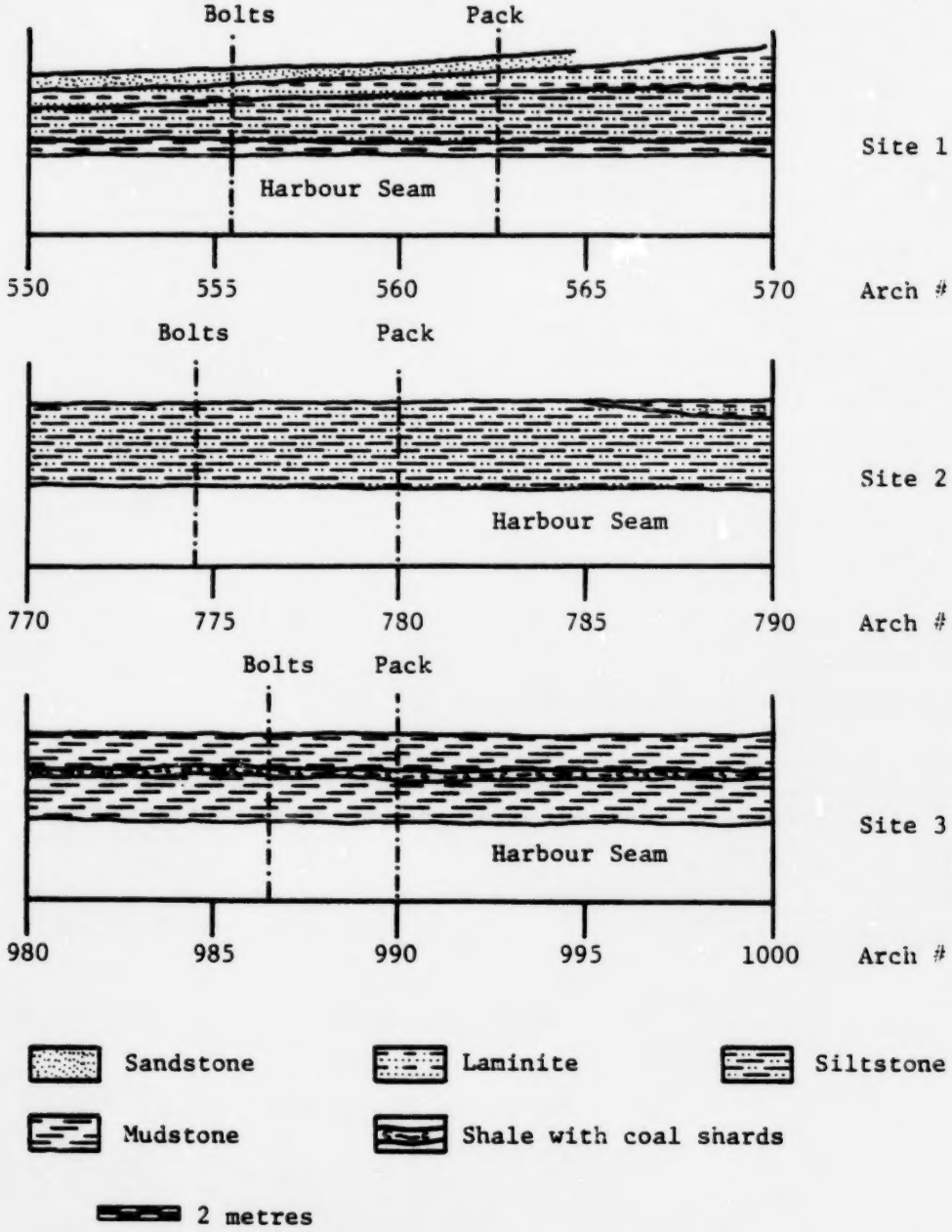


Figure 7 - Detailed roof lithology at the investigation sites in the 9E Maingate

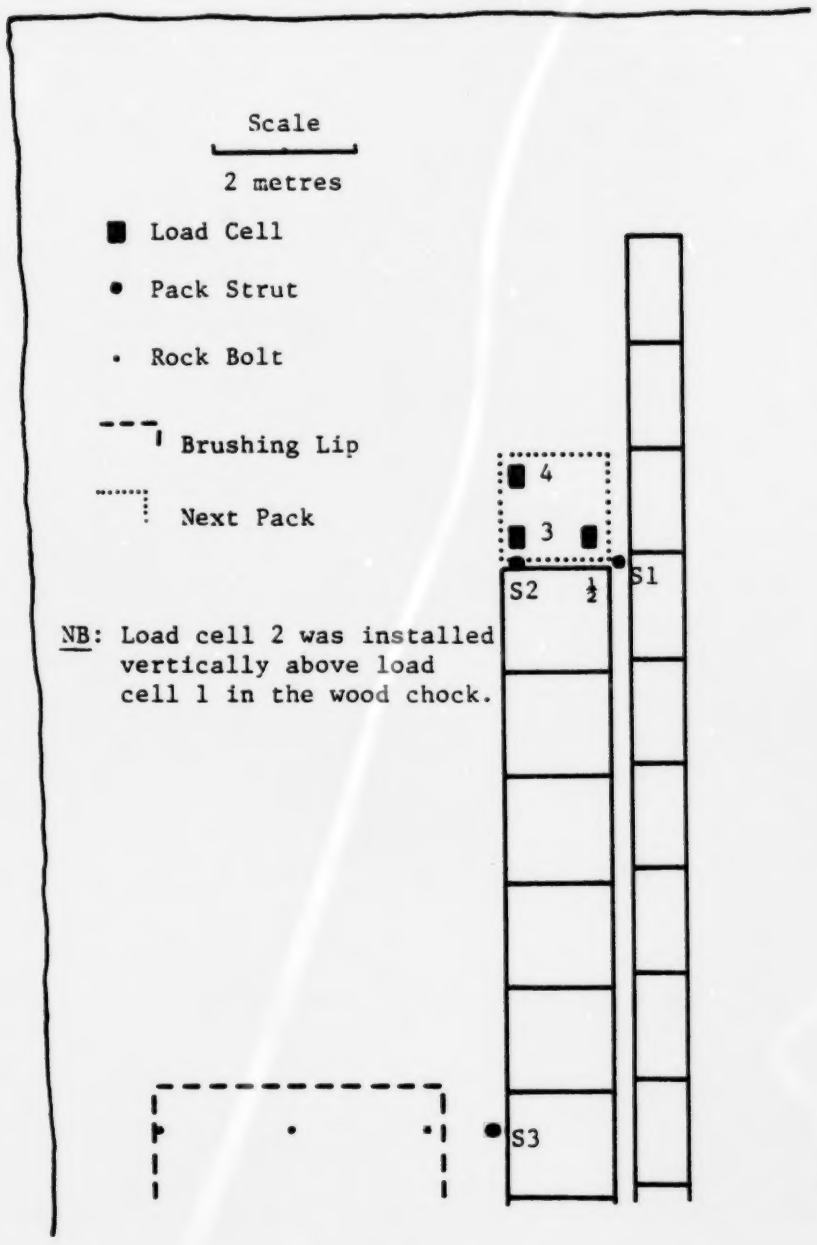


Figure 8 - Layout of the 9E Maingate face end and instrumentation at the installation of Site 1

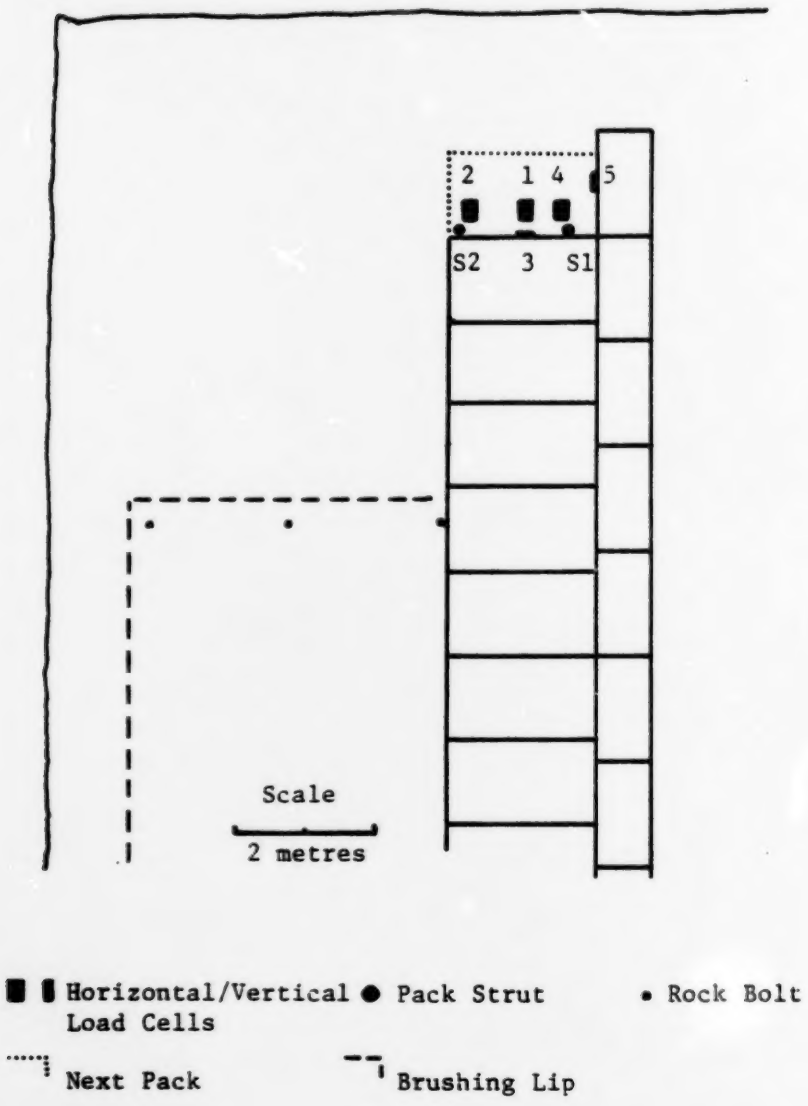


Figure 9 - Layout of the 9E Maingate face end and instrumentation at the installation of Site 2

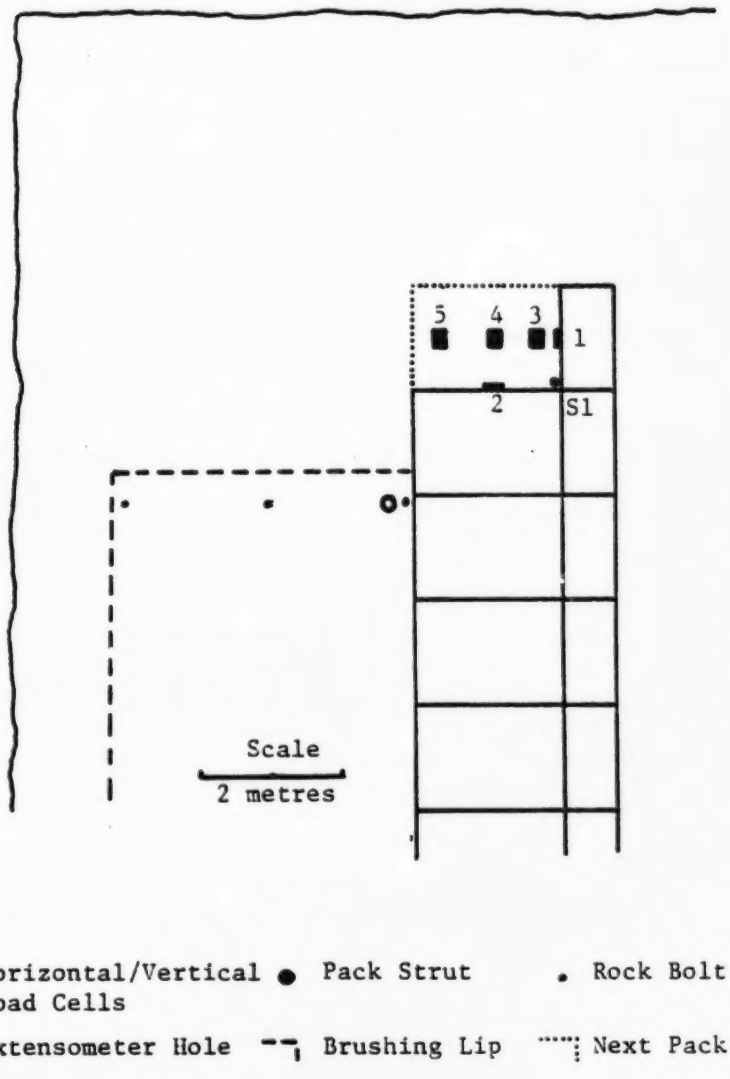


Figure 10 - Layout of the 9E Maingate face end and instrumentation at the installation of Site 3

RESULTS

Results are presented for the site monitoring, additional monitoring and the pumped pack properties testing.

INSTRUMENTED SITES

Convergence and pack stress data collected during the monitoring program for individual sites are presented in Figures 11 to 13. Instrument failures (summarised in Table 8) and erratic readings from convergence bolts makes the identification of gateroad deformation process very difficult. For this reason the graphs of the raw data were treated manually, smoothed and adjusted for easier interpretation. This entailed averaging of load cells at individual sites and offsetting of closure curves to reflect different face locations at installation. These adjusted curves are shown in Figures 14 and 15.

Table 8 - Summary of instrument failures*

	Convergence Bolts	Load Cells	Pack Struts
Site 1	gobside bolt (70 m)[1]	2,3 and 4[2] (0 m)	All (70 m)[2]
Site 2	All (0 m)[3]	2 (20 m)[4]	S2 (15 m)[2]
			S1 (60 m)[2]
Site 3	None	1 (20 m)	S1 (20 m)[2]
		4 (20 m)	
		2 (70 m)	

The extensometer (Site 3) access tube was sheared through by roof strata movement after 7 days.

Figures in brackets refer to face advance at time of failure.
Superscripts refer to failure modes described below:

1. Dislodged by falling stone.
2. Instrument failure.
3. Vandalised.
4. Readout lines pinched in pack.

*Observed or inferred from results obtained.

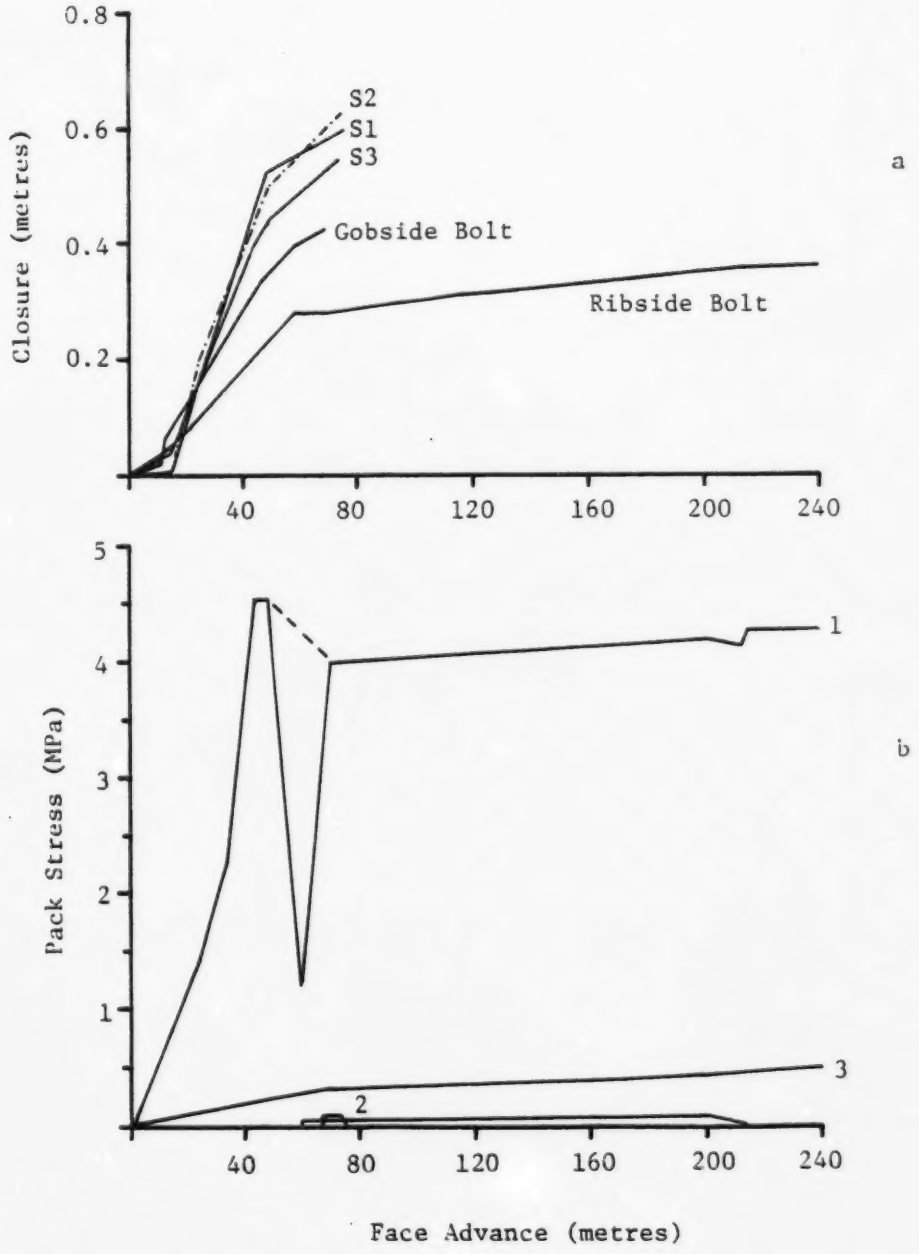


Figure 11 - Results from Site 1: a) closure b) load

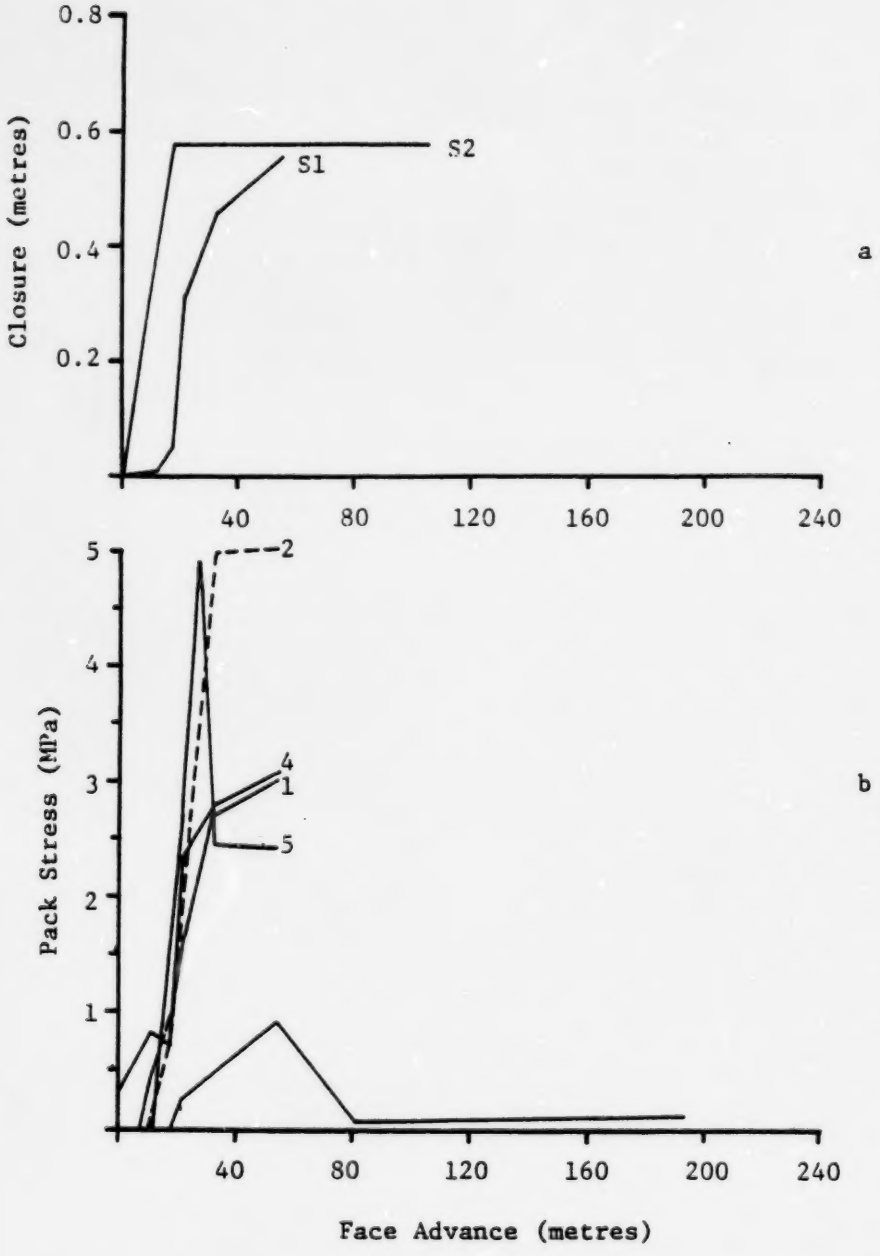


Figure 12 - Results from Site 2: a) closure b) load

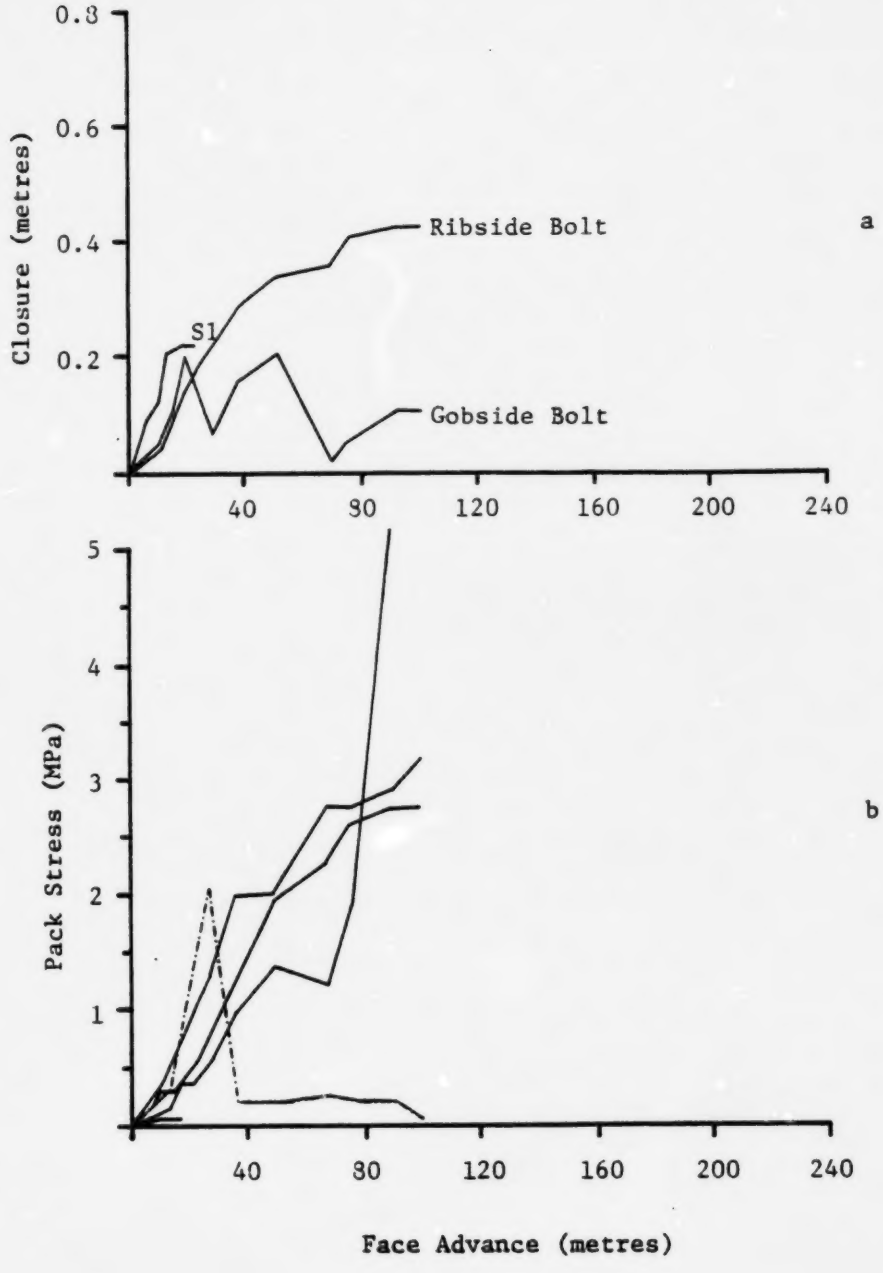


Figure 13 - Results from Site 3: a) closure b) load

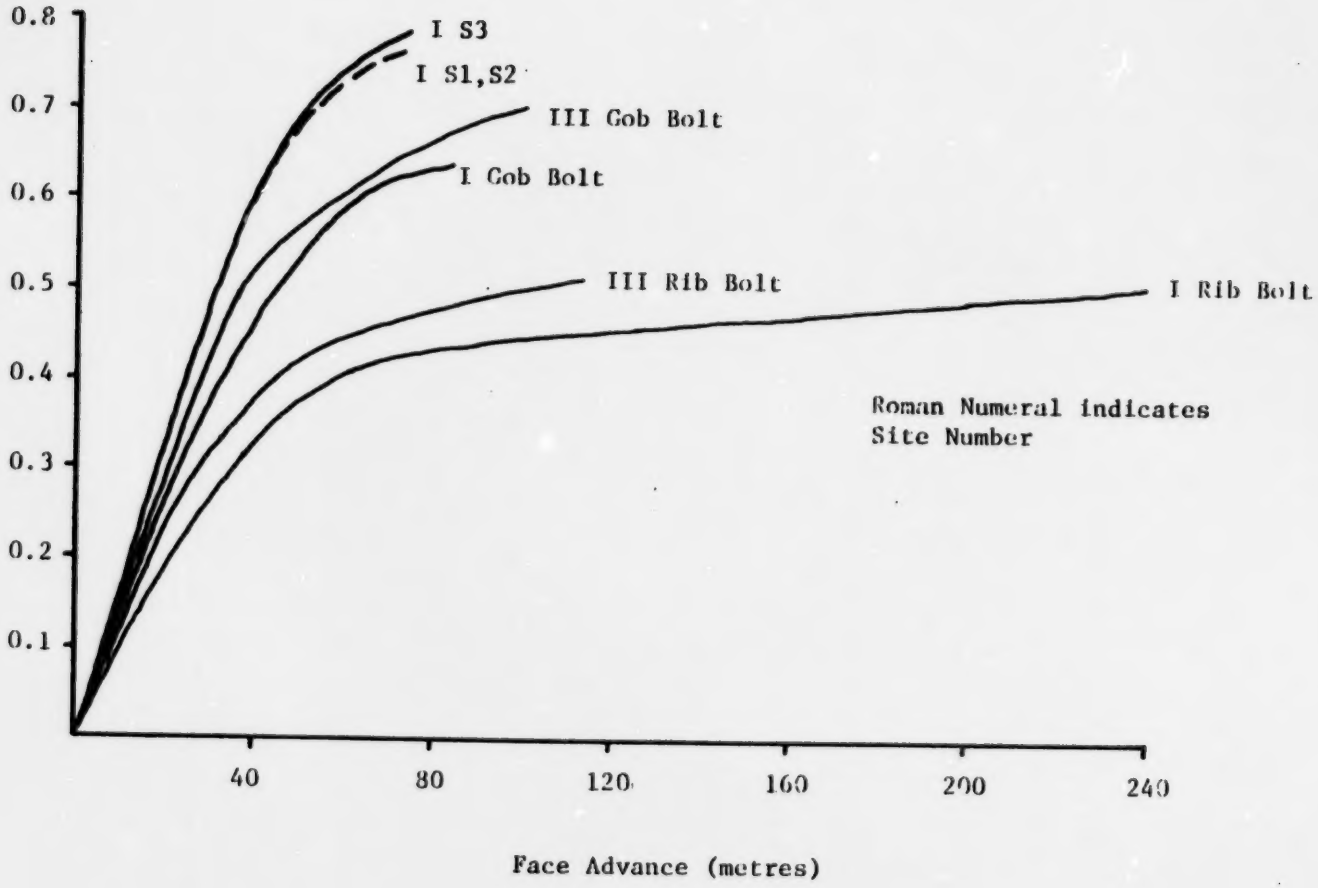


Figure 14 - Adjusted closure results, 9E Maingate

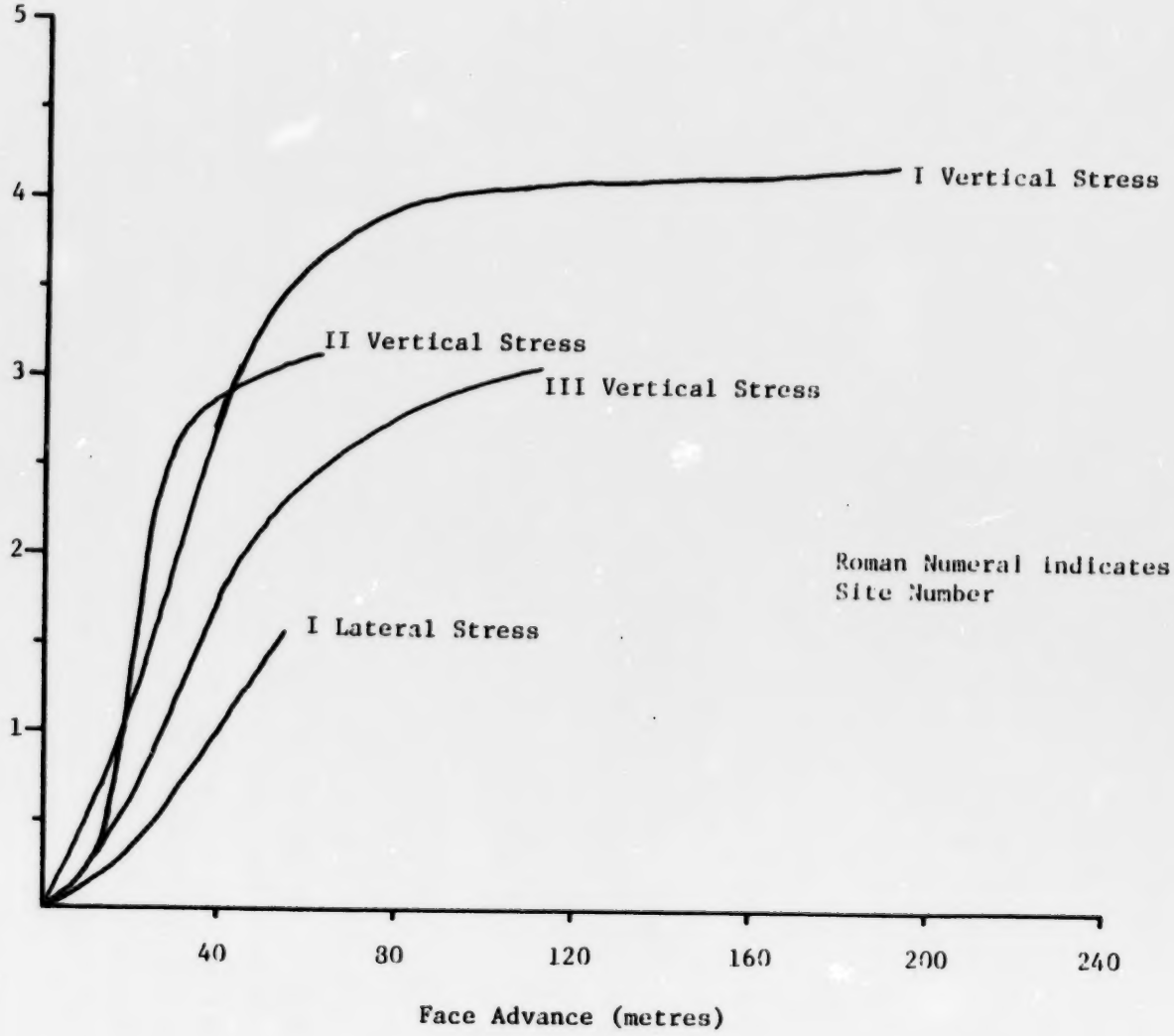


Figure 15 - Adjusted load results, 9E Maingate

Results from each site are very similar and indicate two phases of deformation. Phase 1, representing the effects of immediate extraction, extends to approximately 40 m behind the faceline, after which closures and loads begin to settle into the time dependent Phase II which begins approximately 100 m behind the faceline. Pack stress rise at Site 2 is noticeably more rapid, alternating to the Phase II state after only 40 m of face advance.

ADDITIONAL MONITORING

Additional monitoring activities fell into three categories: 1) survey levelling to determine relative roof and floor closure, 2) gateroad surveys to determine overall deformation characteristics and 3) monitoring of face advance.

Survey levelling proved inconclusive due to removal of or adjustments to the measurement bolts in the gateroads. Two gateroad height surveys were conducted in which clearance from the arch crown to the roadway floor was measured every tenth arch along the entire gateroad. Both gave very similar results, represented graphically in Figure 5 as one curve. Face advance in two-week time increments is also illustrated in Figure 5.

DISCUSSION

The information given above reveals only two marked differences between each of the investigation sites; the roof geology and the method of packing. Sites 1 and 2 are directly comparable, being in the same geological setting and differing only in packing method. However, the absence of closure data for Site 2 makes such a comparison impossible. Pack load data for Site 2 reveals a more rapid load development there compared with the other sites. In the absence of closure data, this is difficult to evaluate, but it could be due to several factors acting singly or in combination:

a) a higher cement content in the Site 2 pack, giving a more rapid strength development in the early stages,

b) closures at Site 2 immediately behind the faceline due to the stronger roof strata, allowing maximum strength and stiffness development in the pack prior to subsequent loading, and

c) less pack confinement on the gobside and roadside at Site 3.

Closure results at Sites 1 and 3 indicate very little difference between the two sites, although convergence at Site 3 is marginally higher. The progressively increasing closure from ribside to the pack suggests that the concept of a beam cantilevered and tilting from a point in the coal rib as described by Smart et al. (6) is also applicable here. Table 9 shows data summarised from Table 6 and Figures 8 and 10, which allows the magnitudes of beam tilt and the location of the notional pivot point to be determined as in Figure 16. Table 9 also contains the results of these calculations.

This concept suggests three stages of gateroad roof beam tilt influenced by the subsidence of the overlying bridging beds (Figure 16). The stability of the gateroad is best served by maintaining the roof beam tilt to within the limits of Stage 1.

In practice, roof strata tilt can be determined by either of two methods (Figure 17). Roof strata tilt was determined for Site 1 in the 9E Maingate from the convergence data, the distance between each closure station (rib bolt, gob bolt and pack strut) having been measured at installation. Three curves were derived representing tilt between three stations (Figure 18). Stage 1 deformation ends 15 m behind the coalface at 1.3° tilt as the curves diverge. The divergence is almost certainly due to the penetration of the floor by the hardwood chock. Stage 2 deformation became predominant approximately 70 m behind the faceline, when the rib bolt - back strut tilt is approximately 3°.

Failure of the convergence stations at Sites 2 and 3 make a full comparison of the tilts experienced in the 9E Coal Road impossible but rib bolt - gob bolt tilt at Site 3 matches that at Site 1 almost exactly. It would be expected that the wider pumped pack, with a more evenly distributed load, would reduce the amount of floor penetration.

The gateroad survey results also tend to agree with the conclusion that the stability of the gateroad has been maintained, but also that closures will ultimately be less in the zone of mudstone roof and pumped pack. This is as yet unproven due to the proximity of the faceline to the roof geology transition point at the time of the survey. An additional observation is that the first 300 arches of face advance are subject to less closure, possibly due to bridging of the strata across the substantial pillars at this point and therefore resulting in incomplete gob compaction. This would

Stage 1 - Roof Strata Tilt Increasing
Stage 2 - Roof Strata Tilt Constant
Stage 3 - Roof Strata Tilt Decreasing

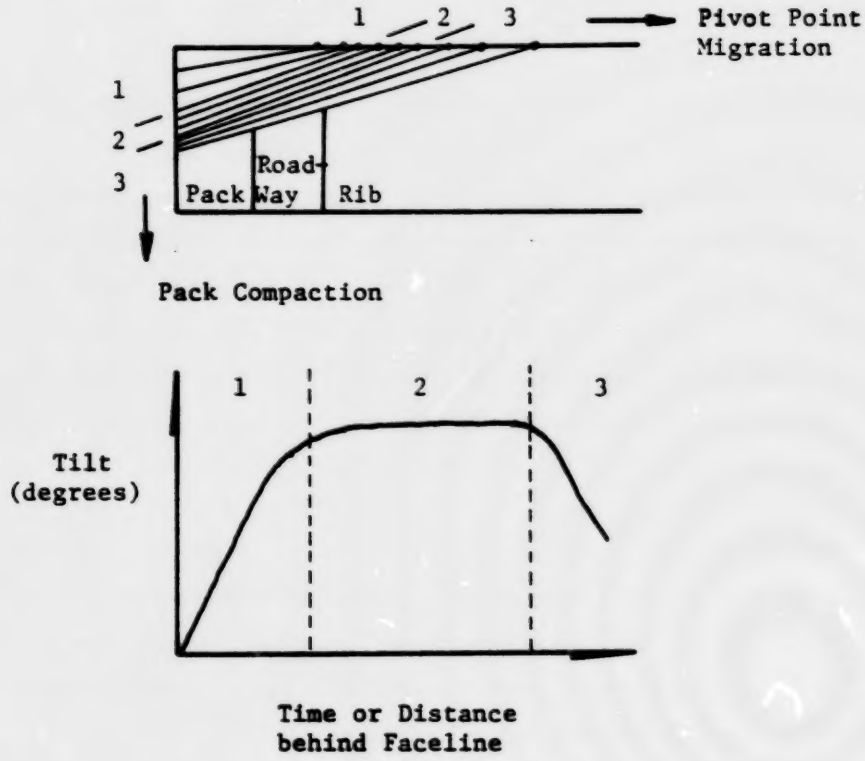
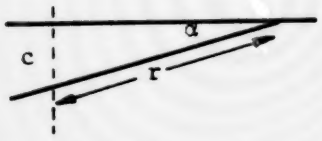


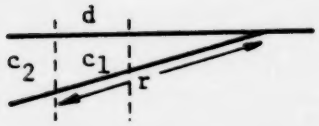
Figure 16 - Stages of roof beam tilt

Lines of Measured Convergence



c and α measured

$r = c/\alpha$



Lines of Measured Convergence

$c_1 c_2 d$ measured

$$\alpha = \frac{c_2 - c_1}{d}$$

$r = c_2/\alpha$

c = Measured Convergence

d = Distance between Convergence Points

α = Tilt in radians

r = Radius to Pivot Point

Figure 17 - Determination of tilt and pivot point locations

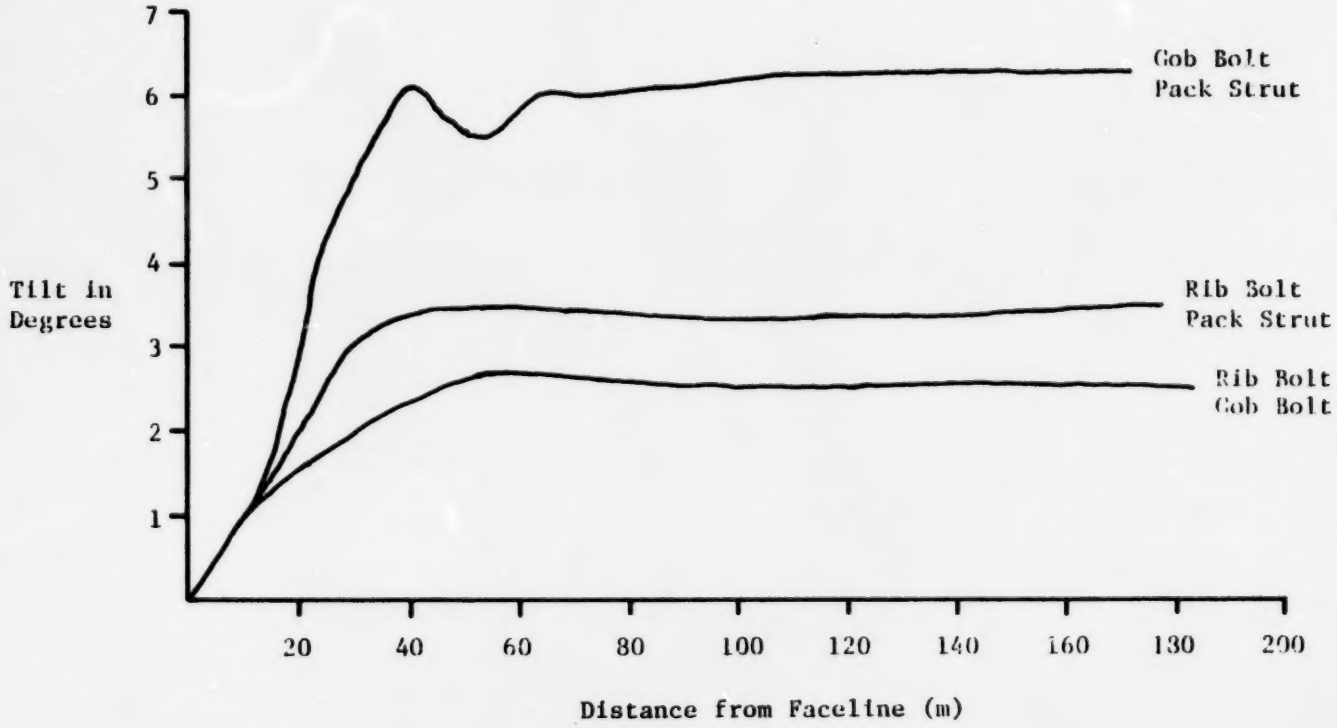


Figure 18 - Roof beam tilt curves for Site 1

result in higher ventilation losses in this area, a conclusion reflected in practice. The maintenance of an efficient gob seal in this zone is therefore of utmost importance to the improvement of ventilation efficiency.

The original design for the 9E Coal Road pumped pack was formulated on the basis of results from the 8E Coal Road, which indicated a support resistance of 6.75 - 8 MN/m of gateroad. This is the total pack resistance at the start of Phase II of the deformation process. Results from the 9E Coal Road give resistance of 5.85 MN/m and 6.3 MN/m for the conventional and pump packed section respectively. Although comparable, these are lower than those experienced in the 8E Coal Road, possibly due to a difference in the site conditions. It should be noted that the original concept of a 1.5 m pack would offer only 4.5 MN/m of resistance on the basis of these results, well below the required value.

The overall conclusion to be drawn from the results is that the stability of the gateroad has been maintained, although observation should be continued to monitor long-term effects and changes in site specific parameters.

CONCLUSIONS

The following conclusions can be drawn from the results of the 9E Maingate pump pack trial monitoring programme.

1. The gateroad deformation process is similar to that found during other gateroad investigations at Lingan Colliery and elsewhere in the world.
2. The differential convergence recorded between the ribside and the pack supports the theory that the immediate strata behave as a beam, with a pivot point somewhere in the coal rib.
3. Gateroad behaviour at all three sites is similar, with minor differences in closure and pack load development attributable to site conditions.
4. The change to a pumped pack as the primary means of gateroad support appears to have had no detrimental effect on the gateroad in terms of strata control, although one possible effect, floor heave in the pumped pack section, was not investigated.

RECOMMENDATIONS

The following recommendations are derived from the discussion of results.

1. Short-term effects of monolithic packing should be investigated further, with particular emphasis on the use of extensometer and survey levelling to determine the extent of floor heave.
2. Long-term effects of the packing trial on gateroad stability should be determined by the repetition of gateroad surveys at intervals throughout the life of the panel.
3. Instrumentation installation practices should be reviewed to eliminate unnecessary instrument failure. A continuing education programme should be adopted in the mines to try to prevent vandalism of investigation sites.

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APPENDIX A
CALCULATION OF REQUIRED PACK WIDTH

Results from instrumentation sites in the 8E Coal Road at Lingan Colliery indicated pack loads of 4.5 - 5.5 MN/m^2 after 27% pack strain. This occurs after 100 m of face advance, after which time pack loads and rate of closure stabilise. A pack strain of 27", when analysed in conjunction with closure results from other stations in the roadway, reflects a tilt of the overlying roof strata of approximately 3°. This represents the limit of gateroad stability. Further deflection of the roof beam will result in major roof breaks and deterioration of the roadway. The value of 3° has been found to be applicable in a wide variety of coal mining conditions. Ideally, the monolithic pack will restrict roof beam tilt to 3° or less by offering the same resistance as the existing pack.

The support resistance offered by the conventional pack can be expressed in MN/m length of roadway by dividing the pack load by the pack width. Thus the support required from the new packing system is 6.75 - 8.25 MN/m.

A value for the support offered by a monolithic pack can be deduced by examining its in situ stress/strain characteristics. Unfortunately field data for 'Astrapack', the proprietary blend chosen by CBDC for the trial, was not available, so data from in situ monitoring of 'Aquapack', a similar material used at Hem Heath Colliery in Great Britain was used (Figure A-1). The data illustrates the in situ stress/strain characteristics of 'Aquapack' mixes of varying cement composition, expressed as a percentage cement by weight. Curve 3 is the ideal - 14% cement.

Extrapolating curve 3 to 27% strain and multiplying the expected stress by the pack width of 1.5 m gives a theoretical support resistance of 8.25 MN/m. Monolithic packs of 1.82 m, 2.13 and 3 m width will achieve the same support resistance after 24%, 22% and 19% closure, respectively.

Thus the calculation indicates that an 'Aquapack' pumped pack of 1.5 m width would provide the required support. There are, however, several reasons why a wider pack should be considered.

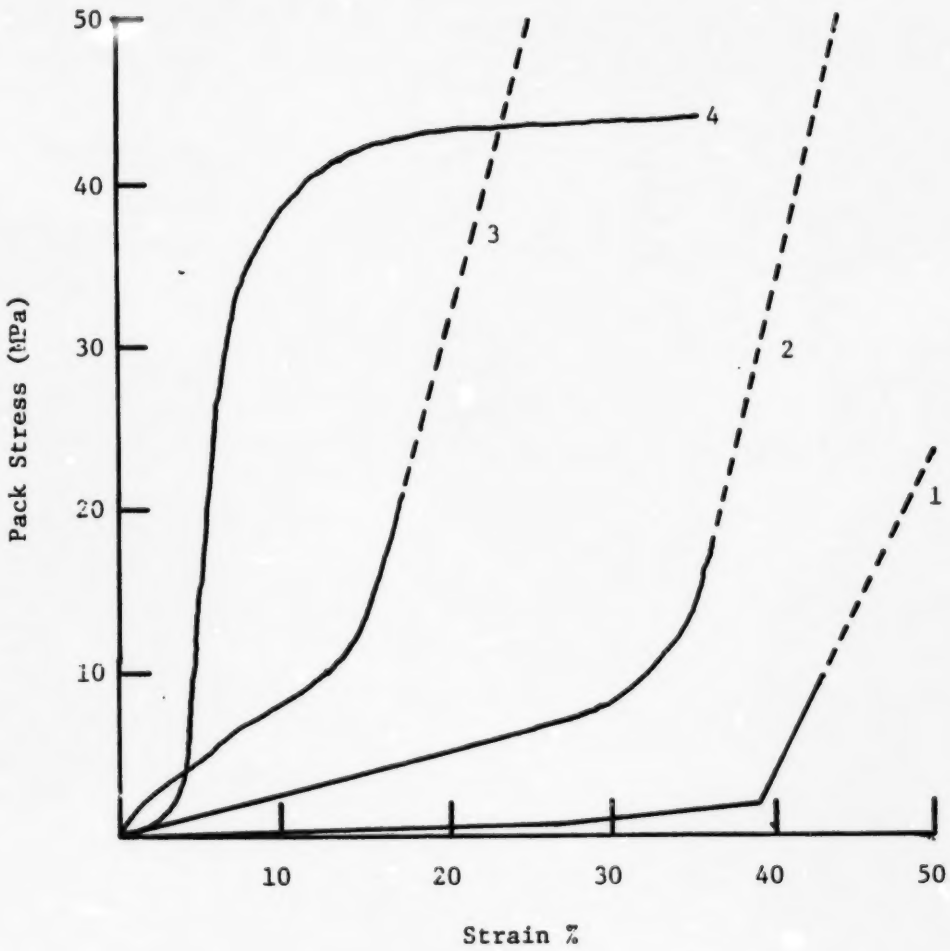
1. 'Astrapack', the material chosen for the trial, has a lower solids content than 'Aquapack', the material on which the calculations are based. The in situ stress/strain characteristics of 'Astrapack' can be reasonably expected to be inferior to those of 'Aquapack'.
2. Low solids cement based packing systems are extremely sensitive to variations in component concentration (Figure 1). To ensure the

success of the trial in the early stages it would be prudent to include a safety factor in the pack width.

3. Cement curing time and strength development is temperature sensitive. Low ambient temperatures which might occur during winter months have been the cause of slow strength development elsewhere.

The recommended pack width, therefore should be greater than 1.5 m. The face end layout in the 9E Coal Road will conveniently allow a pack width of 2.1 m without major changes of the powered supports. This width was therefore recommended.

Key: 1 - 'Aquapack' 15% cement by weight[1]
2 - 'Aquapack' 10% cement by weight[1]
3 - 'Aquapack' 14% cement by weight[1]
4 - 1.5 m x 1.5 m 80% Hardwood Chock[2]



1 - Daw Mill Colliery, U.K.
2 - Lingan 8E Maingate

Figure A-1 - Stress/strain curves for 'Aquapack' and a hardwood chock

APPENDIX B

THE 'ASTRAPACK' PACKING SYSTEM AT LINGAN COLLIERY

Very high levels of air leakage through the longwall wastes threatened to disrupt production on the east side of Lingan Colliery where two adjacent longwalls were operating. Details of gob leakage are given elsewhere (1,2).

In order to alleviate the leakage problem, the Cape Breton Development Corporation (CBDC) opted to install a monolithic pump packing system in the 9E Coal Road (Figure 1) to improve gob sealing and reduce leakage. This measure was recommended but not addressed in a review of gateroad sealant technologies commissioned by CANMET, Cape Breton Coal Research Laboratory (CBCRL) in 1984 (3). Some experience with monolithic packing existed within CBDC as a result of a trial of an 'Aquapack' pump packing system on the 3W Coal Road in the spring of 1982. In this instance the pack width was only 1 m and the result was more in line with a gateroad sealant than a fully supportive pumped pack.

To economise for the trial period, CBDC chose to use the 'Aquapack' placement equipment which was refitted in the colliery workshops. Since the 1982 trial, developments in pumped pack cement technology had resulted in the commercial availability of two similar products which required 20% less material than the 'Aquapack' system. Both products are manufactured in the United Kingdom; 'Tekpack' by Foseco has been used there with some success for 18 months. 'Astrapack' by Pozzament Cements Limited is a relatively new competing product. Both products comprise two components, a high alumina cement blend ('Tekcem' and 'Astracem' respectively) and a bentonite/accelerator blend ('Tekbent' and 'Astrabent' respectively) which are mixed separately and pumped to the packhole prior to entering a bag which holds the mix until it sets. Mix ratios required for these three systems are given in Table 1. 'Astrapack' was chosen for the 9E trial over 'Tekpack' as the result of a competitive bidding process.

UNDERGROUND INSTALLATION

The underground installation of the pump packing system employs two mixing/pumping stations for the 'Astrabent' and 'Astracem' slurries.

The 'Astrabent' mixing/pumping station is located at the junction between the 9E Coal Road and No. 4 Deep. A Colcrete type 5D continuous colloidal mixer is connected to an Evans MK 64 piston pump. Both are

powered from the same electrohydraulic power-pack comprising a 55 kW (75 hp) electric motor coupled by a Reynolds chain to a Colcrete hydraulic pump delivering 64 L/min (14 Imp gal/min) to the pump and 45 L/min (10 Imp gal/min) to the mixer. The hydraulic pump is cooled using water from the mine main which is reduced from 3.44 MPa (500 psi) to 1.4 MPa (200 psi) at a pressure reducer prior to use. 'Astrabent' is fed into the mixer at the rate of 25 kg/min (55 lb/min) from an integral hopper via a vertical screw feeder powered by the hydraulic pump. The colloidal mixer is set at 1000 rpm with a water feed of 64 L/min (14 Imp gal/min). Feed rates, mixer speeds and pump output are regulated and calibrated by controls on the mixing/pumping stations. Station dimensions are given in Table B-1.

Table B-1 - Dimensions of mixing/pumping station components

Component	length (mm)	width (mm)	height (mm)
Power-pack	2700	1000	1000
Mixer	1650	920	1180
Pump	3250	715	900

The mixed 'Astracem' slurry is pumped to within 100 m (300 ft) of the face in 2.5 cm (1 inch) diameter water pipe at which point flexible hose is used to carry the slurry to the mixing/delivery nozzle at the packhole.

The 'Astracem' station straddles the floor mounted stageloader approximately 30 m (100 ft) from the coalface. The mechanical details, feed rates and flow rates are exactly the same as those of the 'Astrabent' station except that 'Astracem' is the material used to make the grout. The 'Astracem' is then pumped in 2.5 cm (1 inch) diameter flexible hose to the mixing/delivery nozzle at the packhole where it splash-mixes with the 'Astrabent' slurry prior to entering the packing bags.

The packing bags are manufactured in Sydney, Nova Scotia from Novathene GMB 2, a plasticised flame retardant anti-static material approved for pump packing use by Labour Canada. The material was developed jointly by Polymer International of Truro, N.S. and Premium Distributors, Sydney, N.S.

and the bags are made and marketed by Premium Distributors. The bags are 2.4 m (8 ft) high, 2.1 m (7 ft) wide and 1.5 m (5 ft) long, and are fitted with ties to allow correct hanging in the packhole. The packs are installed in 1.5 m increments.

In addition to the mechanical elements of the packing system, each pumping station and the packhole has a dedicated communications system to allow control of the pump process.

The pack shutter was made to an NCB (U.K.) design by CBDC. It is a hinged two-piece steel cage with vertically oriented shooting bolts at intervals around the top to allow the packing bag to be raised to the roof. The shutter is supported by four Dowty hydraulic props when the bag is being filled.

PACKING PROCEDURE

The initial stages of the pump packing trial were assisted by personnel from Pozzament Cement Limited and Colcrete Ltd. of the U.K., suppliers of the packing material and pumping machinery respectively.

The first stage of the packing procedure is the erection of the shuttering and hanging of the bag, taking care to ensure that no folds can develop in the bag and that no sharp objects in the packhole can burst it. The 'Astrabent' pump is then activated, delivering 64 L/min (14 Imp gal/min) of 'Astrabent' slurry. When the whitish slurry is observed at the mixing nozzle the 'Astrabent' pump is stopped and the same procedure followed with the 'Astracem' pump. When the dark brown 'Astracem' slurry is seen at the mixing nozzle the 'Astracem' pump is stopped, the mixing nozzle is placed in the packing bag and both pumps are restarted and run until the bag is full. A non-return flap on the packing bag assists sealing when the nozzle is removed upon the completion of the pack.

The specified strength of the 'Astracem' pump packing material after one hour (0.5 MN/m^2, 72 psi) allows the removal of the shutter at that time. The cement pump and line is flushed out after each pack is placed to prevent remnant cement grout from setting in the delivery line. When the pack has set, the shuttering is removed and advanced and the packing cycle begins again.